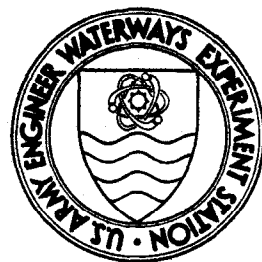


DREDGED MATERIAL RESEARCH PROGRAM



TECHNICAL REPORT D-78-26

HABITAT DEVELOPMENT FIELD INVESTIGATIONS BUTTERMILK SOUND MARSH DEVELOPMENT SITE ATLANTIC INTRACOASTAL WATERWAY, GEORGIA SUMMARY REPORT

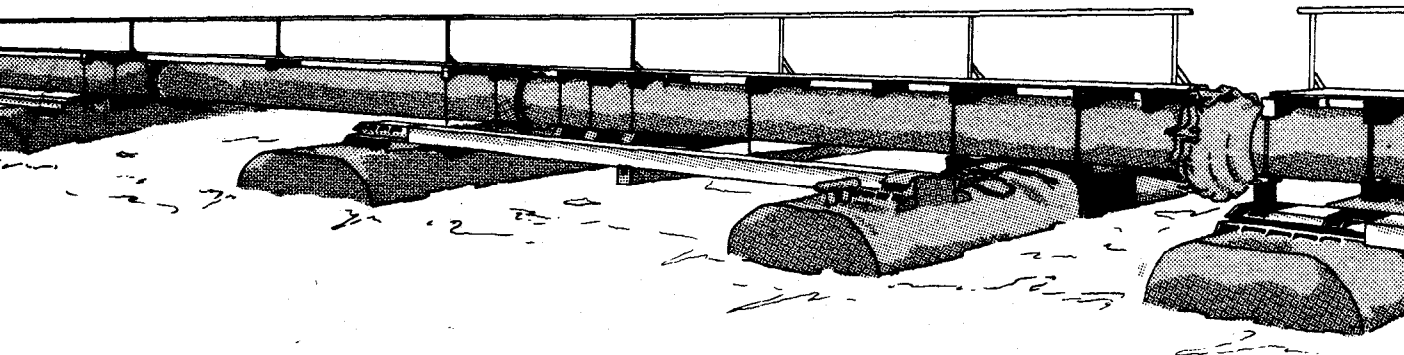
by

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July 1978
Final Report

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Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under DMRP Work Unit No. 4A12A

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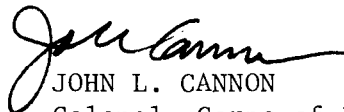
1. The technical report transmitted herewith represents the results of one of a series of research efforts (work units) conducted as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A was part of the Habitat Development Project (HDP) and had as its objective the development and testing of the environmental and economic feasibility of using dredged material as a substrate for marsh development.
2. Marsh development on dredged material was investigated by the HDP under both field and laboratory conditions. This report, "Habitat Development Field Investigations, Buttermilk Sound Marsh Development Site, Atlantic Intracoastal Waterway, Georgia; Summary Report" (Work Unit 4A12A), summarizes the activities that occurred during marsh development studies at Buttermilk Sound, Glynn County, Georgia, between 1975 and 1977. A general discussion of the engineering and biological aspects of salt marsh propagation, microbial development, and associated animal response is presented. The reader is referred to Appendix A to this report entitled "Propagation of Marsh Plants and Postpropagation Monitoring" (4A12A) for a more detailed discussion.
3. A total of nine marsh development sites were selected and designed by the HDP at various locations throughout the United States. Six sites were subsequently constructed. Those, in addition to Buttermilk Sound, include: Windmill Point on the James River, Virginia (4A11); Apalachicola Bay, Apalachicola, Florida (4A19); Bolivar Peninsula, Galveston Bay, Texas (4A13); Pond #3, San Francisco Bay, California (4A18); and Miller Sands, Columbia River, Oregon (4B05). Detailed design for marsh restoration at Dyke Marsh on the Potomac River (4A17) was completed, but project construction was delayed in the coordination process. Marsh development studies at Branford Harbor, Connecticut (4A10), and Grays Harbor, Washington (4A14), were terminated because of local opposition and engineering infeasibility, respectively.

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4. Evaluated together, the field site studies plus ancillary field and laboratory evaluations conducted in Task 4A establish and define the range of conditions under which marsh habitat development is feasible. Data presented in the research reports prepared for this task will be synthesized in the technical reports entitled "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations" (2A08), and "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4A24).

A handwritten signature in black ink, appearing to read "John L. Cannon", written in a cursive style.

JOHN L. CANNON

Colonel, Corps of Engineers
Commander and Director

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A summary is presented of activities that occurred during the habitat development field investigation at Buttermilk Sound near the mouth of the Altamaha River in Glynn County, Georgia, between 1975 and 1977. A general discussion of salt marsh propagation, microbial development, and associated animal responses is included. Detailed information regarding habitat development at this site is presented in Appendix A to this report.		

PREFACE

This report presents a summary of the activities that occurred during a habitat development field investigation at Buttermilk Sound near the mouth of the Altamaha River in Glynn County, Georgia. The investigation was conducted as part of the Corps of Engineers' Dredged Material Research Program (DMRP) under Task 4A, "Marsh Development," of the Habitat Development Project (HDP). The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was assigned to the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss.

The U. S. Army Engineer District, Savannah, conducted an engineering survey, graded the island to the desired slope, and administered the research contract (No. DACW21-75-C-0074). Mr. W. B. Clarkson directed the work.

The Marine Extension Service of the University of Georgia, with Dr. R. J. Reimold as the principal investigator, completed a literature review, conducted a baseline study to inventory and assess environmental parameters at the site, and conducted the field studies at Buttermilk Sound. Others at the Marine Extension Service who had responsibility for various aspects of the project were Dr. W. Bough and Messrs. M. C. Hardisky and P. C. Adams.

This report was written by Dr. Richard A. Cole, Michigan State University and EL, and edited by Ms. L. Jean Hunt, EL. The study was under the general supervision of Dr. John Harrison, Chief, EL, Dr. R. T. Saucier, Special Assistant for the DMRP, Dr. C. J. Kirby, Chief, Environmental Resources Division, and Dr. H. K. Smith, Manager of the HDP. Site managers for the Buttermilk Sound study were Drs. J. S. Boyce and C. H. Pennington.

The Directors of WES during the period of contract study, report preparation, and summary report compilation were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director of WES was Mr. F. R. Brown.

CONTENTS

	<u>Page</u>
PREFACE	1
LIST OF TABLES	3
LIST OF FIGURES	4
PART I: INTRODUCTION	5
PART II: SITE DESCRIPTION	6
PART III: PROPAGATION STUDY	9
Methods and Materials	9
Results and Discussion	16
Summary and Conclusions.....	24
PART IV: MICROBIAL DEVELOPMENT	25
Methods and Materials	25
Results and Discussion	25
Summary and Conclusions	27
PART V: ANIMAL RESPONSE	28
Methods and Materials	28
Results and Discussion	28
Summary and Conclusions	31
PART VI: SUMMARY AND CONCLUSIONS	32
REFERENCES	34
NOTE: Appendix A to this report, "Propagation of Marsh Plants and Postpropagation Monitoring," was reproduced separately.	

LIST OF TABLES

	<u>Page</u>
1 Schedule of Monitoring Dependent Variables at Buttermilk Sound	15
2 Numbers of Abundant Aquatic Species Captured by Trawl and Seine	30

LIST OF FIGURES

	<u>Page</u>
1 Location of the Buttermilk Sound habitat development site	7
2 Site preparation	10
3 Experimental design and treatments used for planting at Buttermilk Sound	12
4 Plant propagation	14
5 Mean total plant biomass, by species, measured in three elevational zones of the intertidal area.....	17
6 Density of three common invaders that withstood the greatest ranges of inundation.....	19
7 Mean root and aerial biomass, by species, in spring and fall..	22
8 Total microbial biomass by elevational zone in the top 0-12 cm of dredged material, in plots with no plants, smooth cordgrass, and saltmeadow cordgrass	26
9 Change of crab burrows and plant stem density over the study period in plots sprigged with saltmeadow cordgrass	29

HABITAT DEVELOPMENT FIELD INVESTIGATIONS
BUTTERMILK SOUND MARSH DEVELOPMENT SITE
ATLANTIC INTRACOASTAL WATERWAY, GEORGIA
SUMMARY REPORT

PART I: INTRODUCTION

1. The U. S. Army Corps of Engineers annually dredges 289 million cu m of sediments, much of it near coastal wetlands. Historically, much dredged material was disposed on wetlands, some of which were among the most productive biological systems on earth and provided food and shelter for commercially and recreationally valuable marine life. More recently, recognition of the natural resource value of wetlands has stimulated the investigation of alternative approaches to dredged material disposal.

2. The Dredged Material Research Program was formulated at the Waterways Experiment Station in 1973 to investigate the management of dredged material disposal in an environmentally compatible manner. One potential use of dredged material is habitat development for desirable biological resources. As part of a nationwide effort to investigate habitat development using dredged material, several field sites were selected for study to represent different regions and situations of dredging activities. The Savannah District of the Corps of Engineers has an ongoing maintenance dredging project in the Atlantic Intracoastal Waterway in Buttermilk Sound, Georgia, which coincided in time and situation with the needs of the program. A study was planned to (a) establish several species of marsh plants on dredged material from this project, (b) monitor their response to site conditions, and (c) document substrate changes, microbial development, and animal presence at the site.

PART II: SITE DESCRIPTION

3. The habitat development site at Buttermilk Sound is located in the Intracoastal Waterway near the mouth of the Altamaha River in Glynn County, Georgia (Figure 1). Most of the surrounding area is low salt marsh with scattered islands, some of which are remnants from dredged material disposal sites and rice farm diking. The marshes are flooded twice daily by a 2-m tide that has cut numerous small creeks.

4. Soil composition varies little throughout the marshes; the surface is a brown, plastic and mildly alkaline clay ramified by fibrous roots. The underlying soil is a red-streaked, gray, plastic clay containing larger quantities of disintegrated plant tissues. The clays are relatively impermeable to water, but hold moisture well. In the higher elevations of the tidal marsh up to 60 cm of firmer, sandier soils overtop the clay. The sand is much more permeable to water than the underlying clay. Further inland occur poorly drained alluvial soils comprised mostly of extremely acid, plastic clay interspersed with plant matter and sand lenses. This area is inundated periodically by spring tides, storm tides, and high river discharges and support brackish-water marsh plants like arrow-arum (Peltandra virginica), pickerelweed (Pontederia cordata), cattail (Typha domingensis), and wild rice (Zizania aquatica).

5. Smooth cordgrass (Spartina alterniflora) is the most common species in the lower tidal marshes, especially along the tidal creeks. At slightly higher elevations in the tidal marsh, the dominants are rough cordgrass (Spartina cynosuroides) or southern wild rice (Zizaniopsis miliacea). On sandy soils of lower salinity in the tidal marsh, the most commonly encountered plants are black needlerush (Juncus roemerianus) and saltmarsh oxeye (Borrichia frutescens). The transition between marsh and land above high tide is dominated by saltgrass (Distichlis spicata), saltmeadow cordgrass (Spartina patens), and marsh elder (Iva frutescens).

6. The study area was a 2-ha island of dredged material resulting from deposition over a 5- to 7-yr period before the study began.

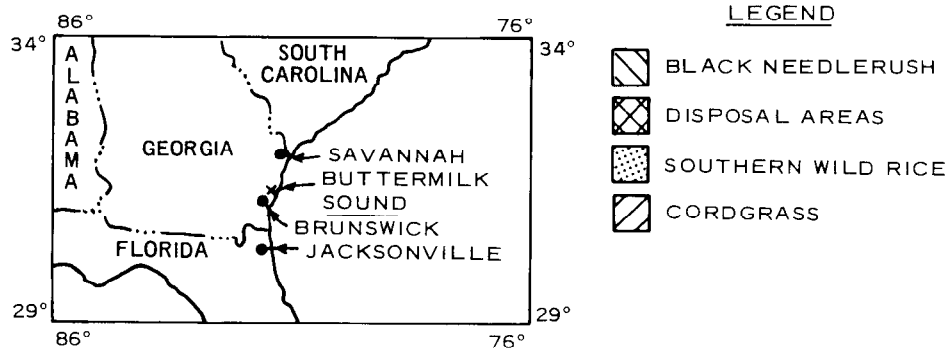
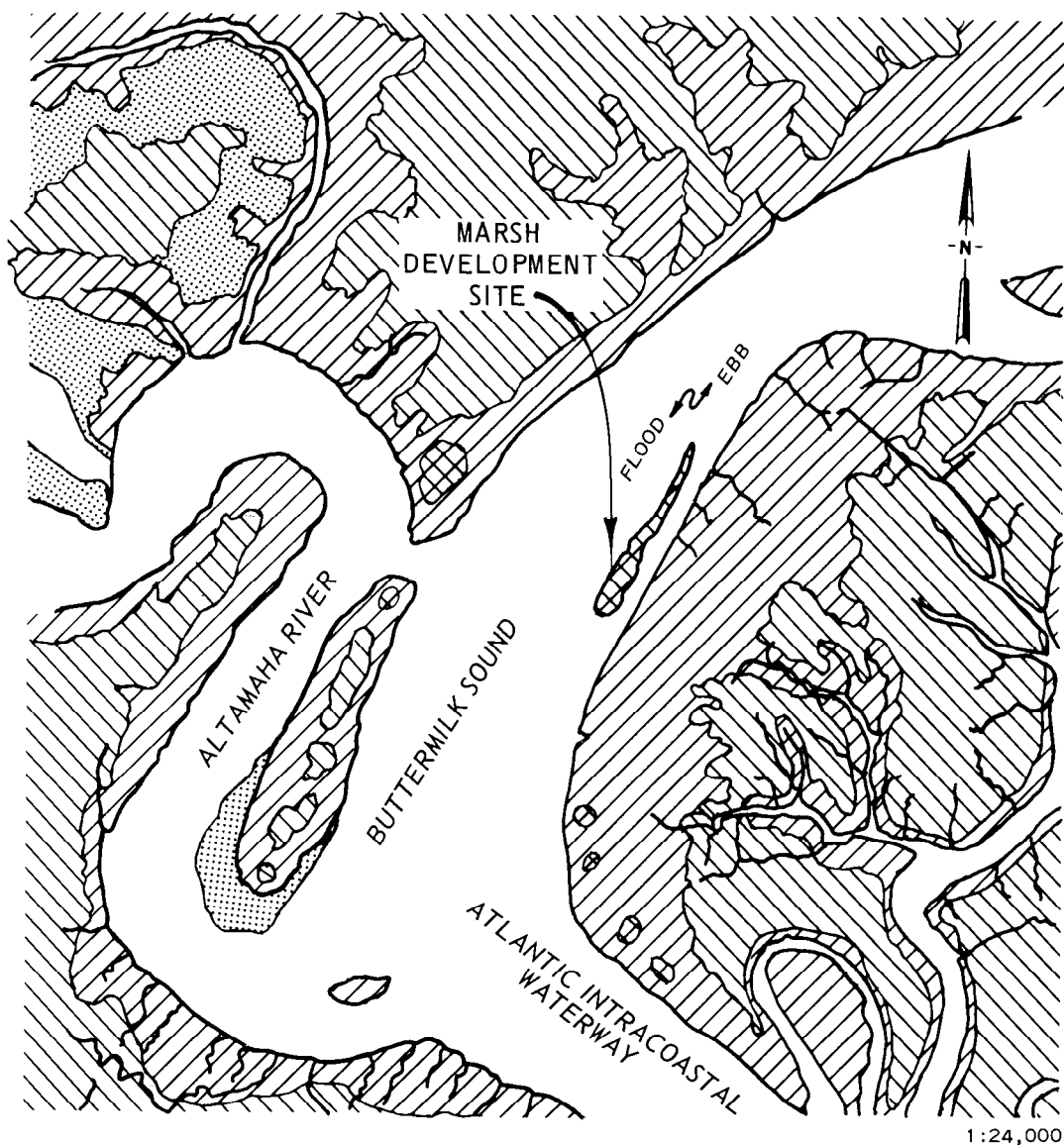


Figure 1. Location of the Buttermilk Sound habitat development site

The island substrate was a chemically homogenous quartz sand mounded to a maximum elevation of 5 m above mean low tide. Plant cover was less than one percent and was comprised mostly of smooth cordgrass.

7. Water surrounding the site is generally fresh to brackish. During the study, salinity was relatively constant and low, usually less than 2 o/oo and attaining a maximum of 7 o/oo in the summer of 1977. Sampling of water chemistry every two months (Reimold et al. 1978) revealed some trends. The redox potential was nearly constant and high, indicating plentiful oxygen; pH was slightly alkaline and varied slightly. Turbidity, nitrate, and nitrite levels were greatest in spring and fall. Phosphorus concentrations peaked in late fall and winter. Variations in water quality seemed to be determined primarily by the Altamaha River, and there was little variation associated with tidal fluctuations. Water temperatures near the experimental site ranged from 3.5°C in winter and 30°C in summer. Mean monthly air temperatures range from 12.3°C in January to 27.8°C in July. Mean monthly precipitation ranges from 7.19 cm in February to 18.90 cm in July. The discharge of the Altamaha River is generally high in summer and fall and low in winter.

8. Some of the most important invertebrate animals in the area include the saltmarsh grasshopper (Orchelimum fidicinium) and the plant hopper (Prokelisia marginata). Commonly occurring vertebrates are alligators (Alligator mississippiensis), gulls, terns, herons, blackbirds, raccoons (Procyon lotor), and muskrats (Ondatra zibethicus). Important animals in the surrounding estuaries include oysters (Crassostrea virginica), fiddler crabs (Uca pugnax), periwinkles (Littorina spp.), mullet (Mugil cephalus), anchovies (Anchoa mitchilli), and white shrimp (Penaeus setiferus).

PART III: PROPAGATION STUDY

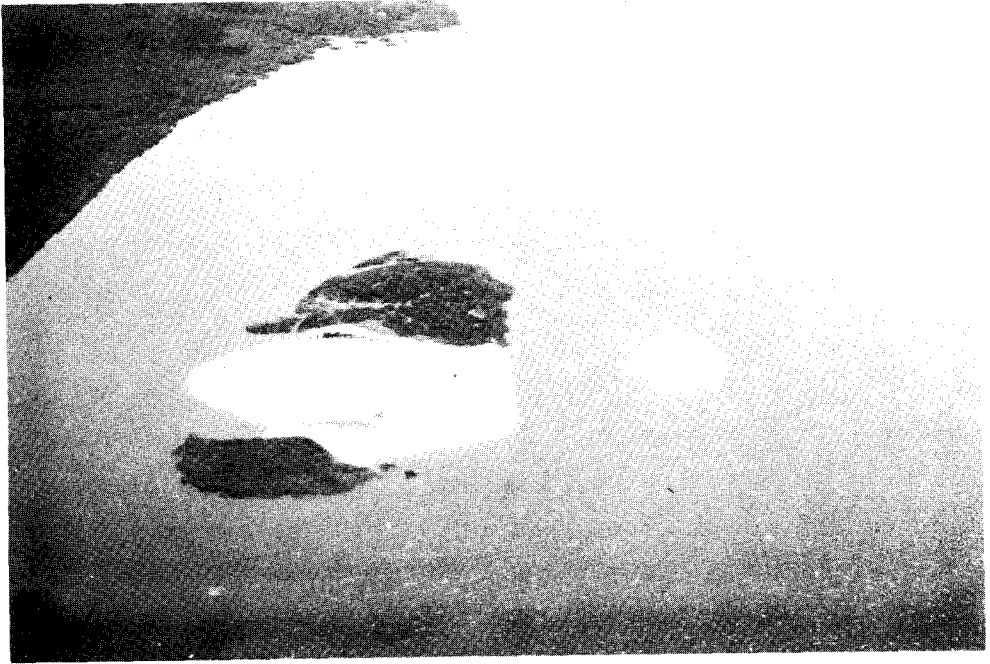
Methods and Materials

Site preparation

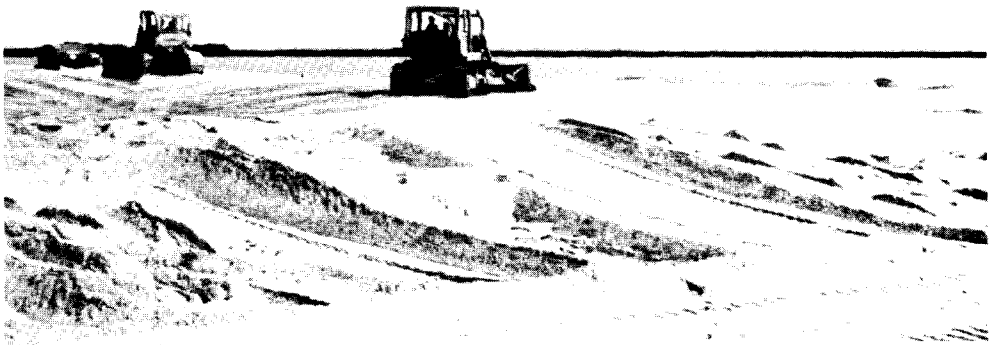
9. The experimental site at Buttermilk Sound was prepared for plant propagation studies in spring 1975. Since no dredging was required at that time within an economical pumping distance from the site, it was decided to rework the existing disposal island. A tidal gauge was installed near the site by referencing a temporary U. S. Geological Survey bench mark. Using readings from the bench mark and tidal gauge, the site was graded to slope with a southwestern aspect from the elevation at mean high tide to the elevation at mean low tide. The average slope over the graded intertidal area was 3.7 percent. The graded site was zoned equally into three elevational zones; the lowest zone was flooded by the tide for over 18 hours each day, the middle zone was covered 6 to 18 hr, and the highest zone was flooded less than 6 hr each day. Figure 2 illustrates site preparation.

Experimental design

10. For experimentation with different propagation procedures, all three zones were divided into three blocks, each of which was subdivided into 80 plots 1.5 x 3.0 m in size. Figure 3 shows the experimental design used to test effects of different combinations of plant species, fertilizer levels, and planting method, i.e. seeding or transplanting, on plant performance. Each of seven species of local marsh plants was seeded and sprigged. They were saltmarsh oxeye (Borrichia frutescens), salt grass (Distichlis spicata), marsh elder (Iva frutescens), black needlerush (Juncus roemerianus), smooth cordgrass (Spartina alterniflora), rough cordgrass (S. cynosuroides), and salt-meadow cordgrass (S. patens). Each resulting combination of species and propagule type was fertilized in five different ways. They were with low inorganic (122 g/m^2), high inorganic (244 g/m^2), low organic (33 g/m^2), high organic (66 g/m^2), and no fertilizer. In addition to those plots planted with the seven species, an eighth set was left entirely unplanted but was fertilized with five different treatments



a. Existing 2-ha island with Atlantic Intracoastal Waterway
on the right



b. Bulldozers grading sandy dredged material to intertidal
elevation

Figure 2. Site preparation (sheet 1 of 2)



c. Island after grading
Figure 2. (sheet 2 of 2)

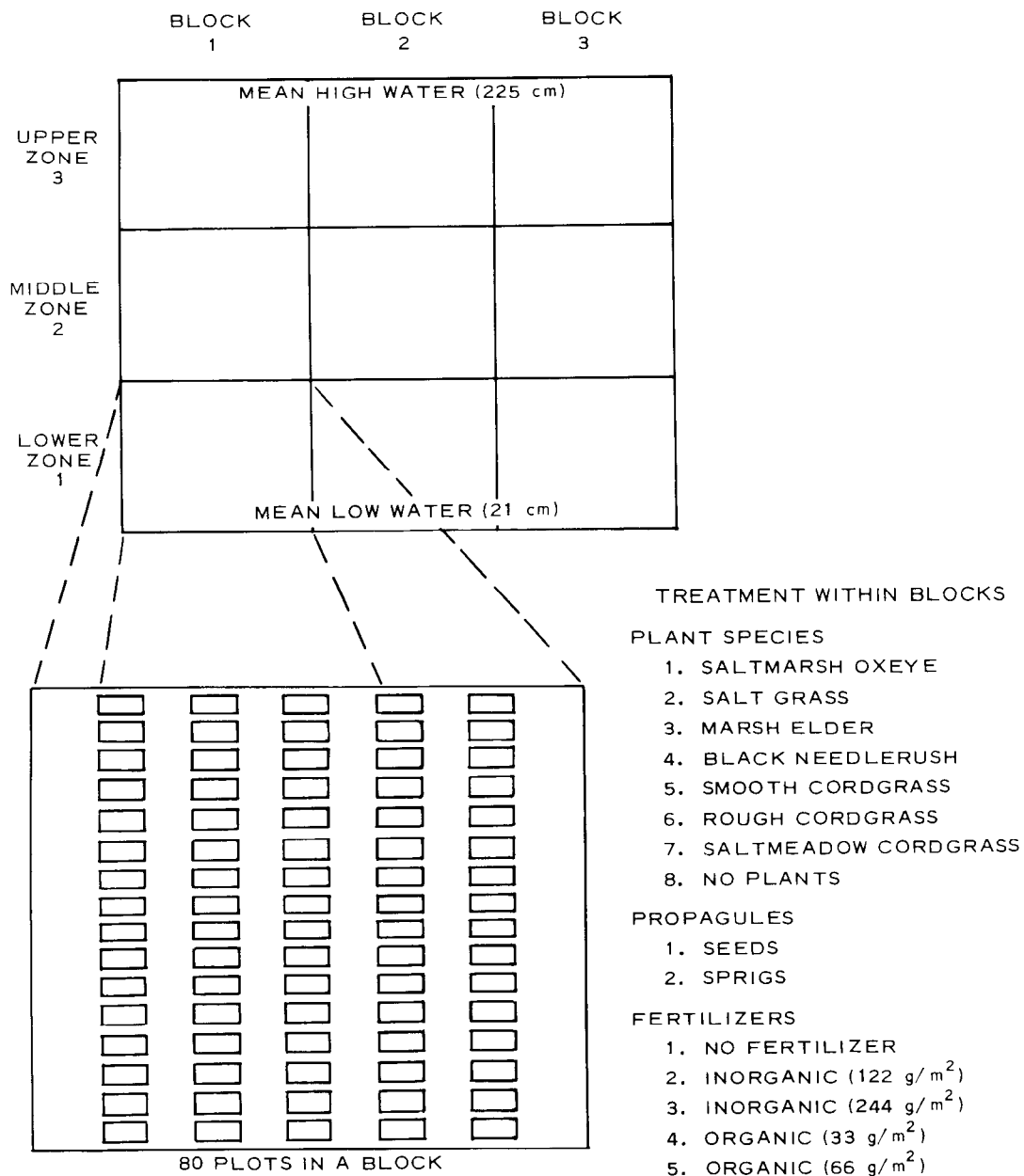


Figure 3. Experimental design and treatments used for planting at Buttermilk Sound

as if it had been planted to an eighth species. All unique combinations of propagation procedures were located randomly within each of the three blocks established for each zone. Thus, each propagation procedure was replicated three times in each zone, once in each block.

11. Propagules of the marsh plant species were collected from sources in nearby estuarine marshes. The plots were sprigged in June 1975 and seeded in April 1976 by hand (Figure 4). Monitoring was conducted according to the schedule indicated in Table 1. About once every two months, the plantings in each plot were checked for their general condition, the density of plant stems, the number of stems in flower, the average height of shoots, and the number of invading species in planted and unplanted plots. For the first growing season, plant survival was recorded to determine any immediate failures. The biomass of roots and aerial growth was estimated in spring and fall months during each year of the study.

12. Many experimental plantings failed in the middle and lower elevation zones during the first year of field work, allowing the opportunity to conduct transplanting studies on smooth cordgrass, a species that did grow well in the middle zone. The objective of these studies was to determine the effect of planting time on survival and performance of transplants. From those plots where original plantings had failed, 91 plots were selected randomly to be planted at a rate of 7 plots every 30 days, beginning in May 1976. The plants were dug from adjacent marshes just prior to planting. They were planted with 10 single culms on 0.5-m centers and monitored for percent survival, aerial and root biomass (dry weight), density of culms, and density of flowering culms. Specifics of all botanical methodologies are reported in Reimold et al. (1978), Reimold and Linthurst (1977), and Hardisky and Reimold (1977).

13. The chemistry of interstitial water was sampled with polyvinyl chloride wells buried to 25 cm and covered with stainless steel cloth to keep out particulates. Fifteen wells were placed in plots planted with smooth cordgrass and 10 wells each were set in saltgrass and saltmeadow cordgrass. The soil water was collected with a syringe and tubing, and analyzed for pH, potential for oxidation and reduction,



a. Raking seeded and fertilized plot



b. Site immediately after planting showing tide covering plots

Figure 4. Plant propagation

Table 1. Schedule of Monitoring Dependent Variables at Buttermilk Sound

Sample Date	Stem Density	Crab Burrows	Root Biomass	Aerial Biomass	Condition	Flowering Stems	Average Shoot Height	Percent Survival	Plant Invaders
July 1975	X	X			X	X			X
September 1975	X	X			X	X	X	X	X
November 1975	X	X	X	X	X	X	X	X	X
January 1976	X	X			X	X	X		X
February 1976	X	X			X	X	X		X
April 1976	X	X			X	X	X		X
June 1976	X	X	X	X	X	X	X		X
August 1976	X	X			X	X	X		X
October 1976	X	X	X		X	X	X		X
December 1976		X			X	X	X		X
January 1977	X	X			X	X			X
March 1977	X	X			X	X			X
May 1977	X	X	X	X	X	X			X
July 1977	X	X				X			X
September 1977	X	X				X			X
November 1977	X	X	X	X	X	X			X

and concentrations of nitrogen and phosphorus.

14. Other soil chemistry measurements were taken from 15-cm deep cores, which were extruded into aluminum foil and transported on ice to the laboratory. The core was divided into segments for analysis, the first segment including most of the active root zone. Subsamples were analyzed for potassium, calcium, magnesium, boron, sulfur, zinc, manganese, iron, copper, cobalt, arsenic, organic matter, pH, Eh, extractable phosphorus, total phosphorus, nitrite, nitrate ammonia, total dissolved nitrogen, total nitrogen, and cation exchange capacity. Details for all soil methodologies are provided in Reimold et al. (1978).

Results and Discussion

Impact of elevation and tidal inundation

15. The survival and growth of propagated and invading plants reflected the effects of elevation and tidal inundation. Figure 5 shows how the mean total biomass of propagated plant species varied in relation to elevation in the three major intertidal zones. Density of all species except smooth cordgrass progressively declined with increased inundation. Only smooth cordgrass survived in the lower zone where flooding exceeded 18 hr each day. At least some plants of all species survived in the middle zone but saltmarsh oxeye, marsh elder, smooth cordgrass, and rough cordgrass were the most successful. With the exception of smooth cordgrass, each plant species grew best in the upper zone where inundation was less than 6 hr each day. Saltmeadow cordgrass grew best of all the species planted in the upper zone and smooth cordgrass the least. Together smooth cordgrass and saltmeadow cordgrass comprised half of the mean total biomass on the experimental site. Among the three zones, biomass was least developed in the middle zone even though all species survived there. In that zone, smooth cordgrass and saltmeadow cordgrass comprised a third of the biomass for all planted species.

16. Aerial biomass for all species in the upper zone at the end of the growing season was similar. However, root biomass differed greatly

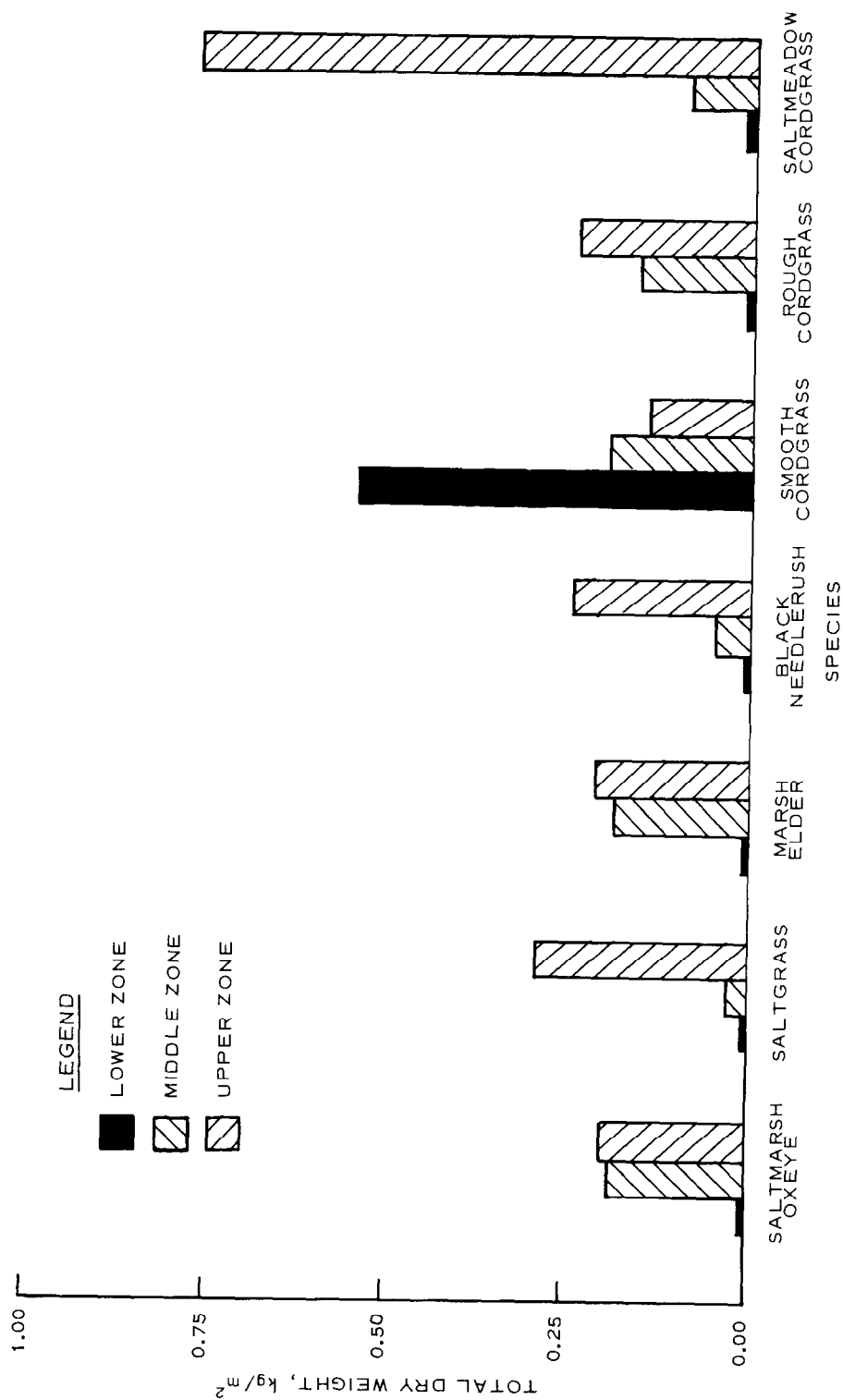


Figure 5. Mean total plant biomass, by species, measured in three elevational zones of the intertidal area

in two species; with the exception of saltmeadow cordgrass, marsh oxeye had substantially more root biomass than all other species. The root biomass of all species was poorly developed in the middle elevational zone.

17. Of the 42 plant species that invaded the experimental plots from May 1975 to November 1977, 4 were encountered more frequently than the rest: water hemp (Acnida cannabinus), panic grass (Panicum sp.), crabgrass (Digitaria sanguinalis), and marsh fleabane (Pluchea purpurescens). Most species invaded the upper zone at elevations more than 1.5 m above mean low tide. Among these, crabgrass grew most densely but was restricted to areas that were inundated no more than 10 hr each day. Panic grass and marsh fleabane also grew densely in the upper zone but extended into lower elevations that were flooded up to 14 hr each day. Water hemp extended further into lower elevations than any plant except smooth cordgrass, withstanding up to 17 hr inundation. Many of the less common invaders including pickerel weed, arrowhead (Sagittaria falcata), three-square bulrush (Scirpus americanus), common bulrush (Scirpus robustus), cattail, southern wild rice, and wild rice reflected the prevalence of low-salinity water around the site.

18. At the end of the study, many more species had invaded the upper zone than the lower zone. By then, 68 percent of all invaders were in the upper zone, 31 percent in the middle zone, and less than one percent in the lower zone. Apparently very few indigenous species can survive more than 14 to 18 hr of tidal inundation each day. Only smooth cordgrass can survive up to 20 hr each day. Three of the more successful invaders of low elevations that might be experimentally planted there are panic grass, water hemp, and marsh fleabane (Figure 6).
Propagules and fertilization

19. Both sprigs and seeds succeeded for all of the species tested. Seeding in April 1976 produced plant densities similar to that resulting from sprigging in the previous year. Both sprigging and seeding initially caused clumped distributions of propagated plants but most species of plants had dispersed enough by the end of the study to resemble a natural marsh. By fall 1977, only sprigged marsh elder and

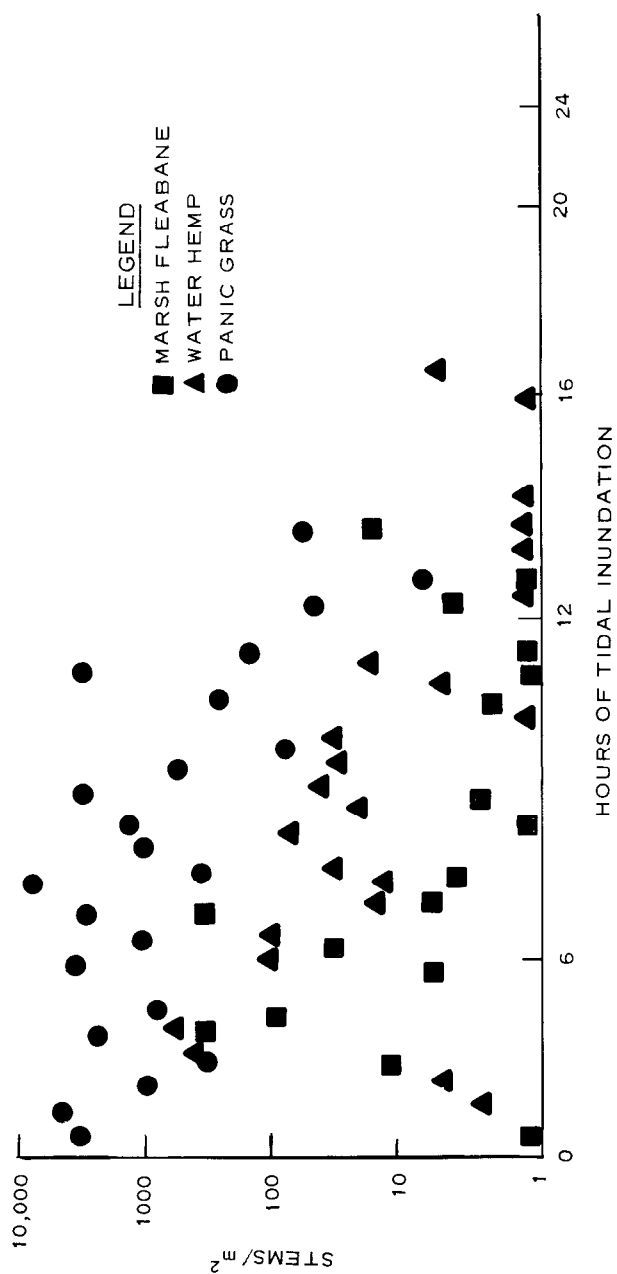


Figure 6. Density of three common invaders that withstood the greatest ranges of inundation

black needlerush remained clumped. Saltgrass dispersed most rapidly, followed by saltmarsh oxeye, smooth cordgrass, and saltmeadow cordgrass. The stem density of sprigged and seeded plants continued to increase over the study period, and had yet to stabilize by the end of the study in fall 1977.

20. Soon after sprigging, most plants became chlorotic and lost most of their leaves. The original sprig usually died within a few months, and few new shoots were produced until the following growing season. The spread of root mass was greater than indicated by aerial portions, so during the second season the density of stems increased remarkably. The success of seeding, however, was high during the first year of planting. By the end of the study, stem density of 2-yr-old sprigged plants slightly exceeded the density of plants that had been seeded 1 year after the sprigs were planted.

21. During the first year of study, in 1975, sprigged plants dispersed little and there was little invasion from outside the experimental area in either planted or unplanted plots. Only the upper intertidal zone was invaded: pickerel weed and coffee bean weed (Sesbania exaltata) became established in 3 percent of the plots. In the following spring, smooth cordgrass invaded 25 percent of the plots in the middle zone and other plants, mostly bulrush, invaded another 9 percent. In the upper zone, only about 13 percent of the area was invaded by this time. One-third of the invasion was from planted species, and the major non-planted invader was water hemp. Sprigged plots were invaded more frequently than the unplanted plots, perhaps because modification of the site's hydraulic energy by the plants caused settling of fine sediment and seed.

22. By the fall of 1976, species usually associated with fresh to brackish waters began to invade the upper zone: yellow nut grass (Cyperus esculentus), water-smartweed (Polygonum punctatum), bulrush, cattail, and water millet (Echinochloa walteri). Some of the planted species also invaded, especially saltgrass, which invaded 16 percent of the plots in the upper zone. An additional 57 percent of the upper zone plots, 77 percent of the middle zone plots, and 18 percent of the

lower zone plots had been invaded by this time. Invaders were most dense in the upper zone. The unplanted plots began to surpass the planted plots in numbers of invaders present. Before this time, invasion of unplanted plots had lagged, indicating that site modifications caused by plant growth enhance invasion rates.

23. By the last year of the study, invasion of the lower zone had ceased, but plants continued to spread into the middle and upper zones. Only smooth cordgrass invaded the lower zone. In the middle zone, the most common invaders were smooth cordgrass, marsh fleabane, and panic grass. In the upper zone, the number of invaders increased dramatically in 1977 and nearly all bare areas were eliminated regardless of their past history. Plots occupied by saltmeadow cordgrass resisted invaders more than other planted species, probably because of the dense mat that was rapidly formed by that species.

24. Fertilization had virtually no effect on survival, stem density, or total biomass of planted species. Regardless of the form of propagation, the response to fertilizer was variable and non-additive. Fertilization also had no influence on the invasion rates found in plots. Apparently fertilizers were removed from the substrate by tidal flushing before the plants could respond.

Stability and accretion

25. One reason for propagating marsh plants on dredged material is to develop resistance to erosion and resuspension of dredged material. Gallagher et al. (1977) found that plants with spreading, fibrous, and somewhat shallow root systems were best for stabilizing alluvial sediments. With this knowledge in mind, an estimate of the total root biomass is a good indicator of substrate stabilizing ability. Those plants that are likely to provide the greatest resistance to erosion are the ones that maintain the greatest mass of fibrous roots near the surface at all times of the year.

26. Figure 7 shows that the root biomass of all plantings varied from spring to fall. In the lower elevation zone, the root biomass of smooth cordgrass, the only species present, varied from a low in spring of 15.5 g/m^2 to 142.4 g/m^2 in fall. In the middle zone, marsh elder

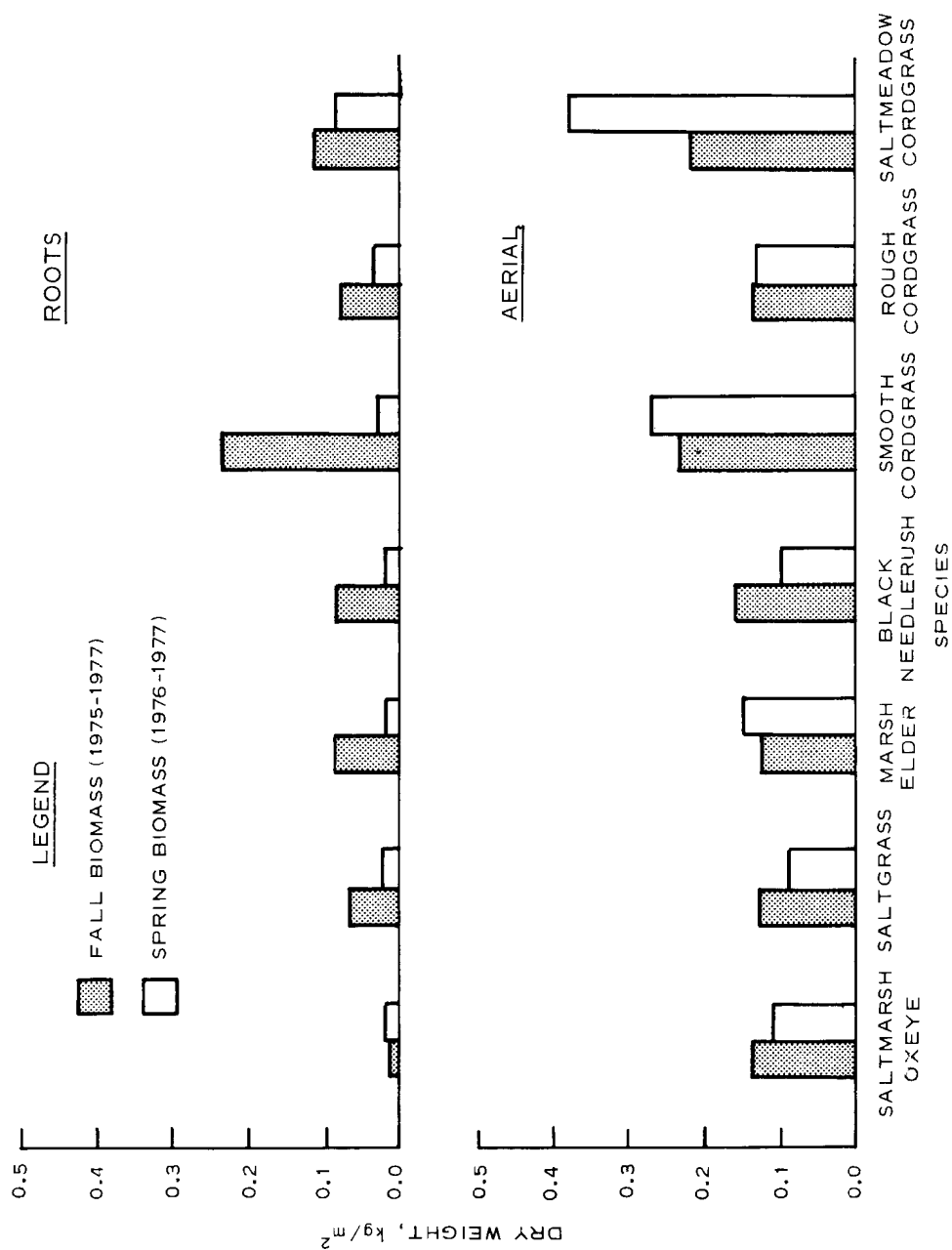


Figure 7. Mean root and aerial biomass, by species, in spring and fall

retained the highest rootmass at the time of the year when rootmass overall was least extensive. But marsh elder has strongly clumped, deep roots that reduce its value for stabilization. Several species in the middle zone demonstrated an irregular distribution of rootmass because of clumping. In the upper zone, saltmeadow cordgrass had the most continuous and highest root biomass; its lowest root biomass was seven times more than that of the next highest species, saltgrass.

27. Considering survival, fluctuation of root biomass, and quality of the root system, it seemed that smooth cordgrass was the only suitable plant for lower elevations and saltmeadow cordgrass and saltgrass were the best choices for higher elevations. Observations of channel development in the experimental plantings confirmed that these three species resisted erosion best in their respective zones. Whether or not the plants were sprigged or seeded appeared to have little impact on their capacity for stabilization.

Time of transplanting

28. There were few statistically significant differences in survival or performance among the transplants of smooth cordgrass. When the performance criteria were examined in total (percentage survival, density of culms, density of flowering culms, and biomass), the best months in descending order were May, April, March, January, and February. These data suggested that the highest probability for transplanting success will be in early spring or winter when temperatures are cool and precipitation greatest. This is consistent with recommendations by Woodhouse et al.(1974).

Soils

29. The temporal changes in nutrients of interstitial water were similar to those in adjacent marshes. No differences were determined among the sets of unplanted plots or plots with different plant species, and fertilizer treatment had no measured effect. The results suggest that a common pool of interstitial water occurs on the entire experimental site. When the sandy dredged material was placed on the site, it had extremely low concentrations of nutrients. During the study, a layer of fine-grained sediments accumulated on the surface and fostered

the infiltration of associated nutrients. Tidal seepage transported the fine-grained particles deep into the sandy dredged material, thereby increasing the concentrations of phosphorus, ammonia, and iron. The soil remained aerobic in most places, but where dense growth of smooth cordgrass occurred the soil began to resemble anaerobic soils of adjacent natural marshes. Although soil nutrients increased during the experiment, concentrations were still lower than those reported for natural areas (Reimold et al. 1978).

Summary and Conclusions

30. The major factor determining the success or failure of plantings at Buttermilk Sound was the elevation and period of tidal inundation. Neither application of fertilizer nor the method of propagation made any difference over time. In this kind of environment, with minimal wave action to wash away the seeds, seeding may be a more effective means of propagating plants than sprigging. However, seeding requires propagule collection, storage, and special handling and consequently involves a large risk element. By comparison, sprigging is easily implemented and more thoroughly tested.

31. Sites with low elevations that are inundated over 14 hr each day may be planted with smooth cordgrass with moderate success. Smooth cordgrass may be transplanted successfully at all times of the year but best results may be expected in early spring and in winter. Other possible candidates for experimentation with plants that can survive in middle elevations include water hemp, marsh fleabane, and panic grass. At higher elevations many planting candidates exist but, for substrate stabilization, the best appear to be salt-meadow cordgrass and saltgrass.

32. A layer of fine-grained sediments accumulated on the surface following the planting and this fostered the gradual, natural enrichment of the nutrient-poor substrate. Where dense growth of plants became established, the soil began to approach that of natural marshes nearby. Given time, the man-made marsh is likely to resemble surrounding marshes.

PART IV: MICROBIAL DEVELOPMENT

Methods and Materials

33. Microbiological research was conducted in plots sprigged with smooth cordgrass, saltmeadow cordgrass, and unplanted plots in all replicate blocks of each intertidal zone. Sediment samples were collected monthly from January to September 1976 in polyvinyl chloride tubes and then cooled with crushed ice until sections (0-2 cm, 5-7 cm, and 10-12 cm) were removed for analysis. Total adenosine triphosphate was measured and bacteria counted. Details for methods and materials are found in Reimold et al. (1978).

Results and Discussion

34. The concentration of adenosine triphosphate in the surface layer increased from January to July, then declined in August and September (Figure 8). Concentrations were greatest on the surface and about the same in the two deeper strata. The presence of plants had no apparent effect on the concentrations. Neither were there significant differences among the three elevational zones. Since accumulation of detritus was least in the lower zone, there was no apparent relationship between the amount of adenosine triphosphate and the detrital accumulation. The amount of adenosine triphosphate found at the study site was 2 to 6 times less than that found elsewhere in southeastern estuaries (Ferguson and Murdoch 1975, Christian et al. 1975), probably because the particle size of the substrate is comparatively coarse at Buttermilk Sound. Dale (1974) found that grain size accounted for 80 percent of the variance in bacterial numbers of intertidal sediments.

35. Distributions of both aerobic and anaerobic bacteria generally resembled the distribution of adenosine triphosphate. Only the middle elevation was sampled but at that elevation no association with plants was found. The bacterial densities at Buttermilk Sound were one to three orders of magnitude lower than at sites investigated by Stevenson et al. (1972) and Dale (1974).

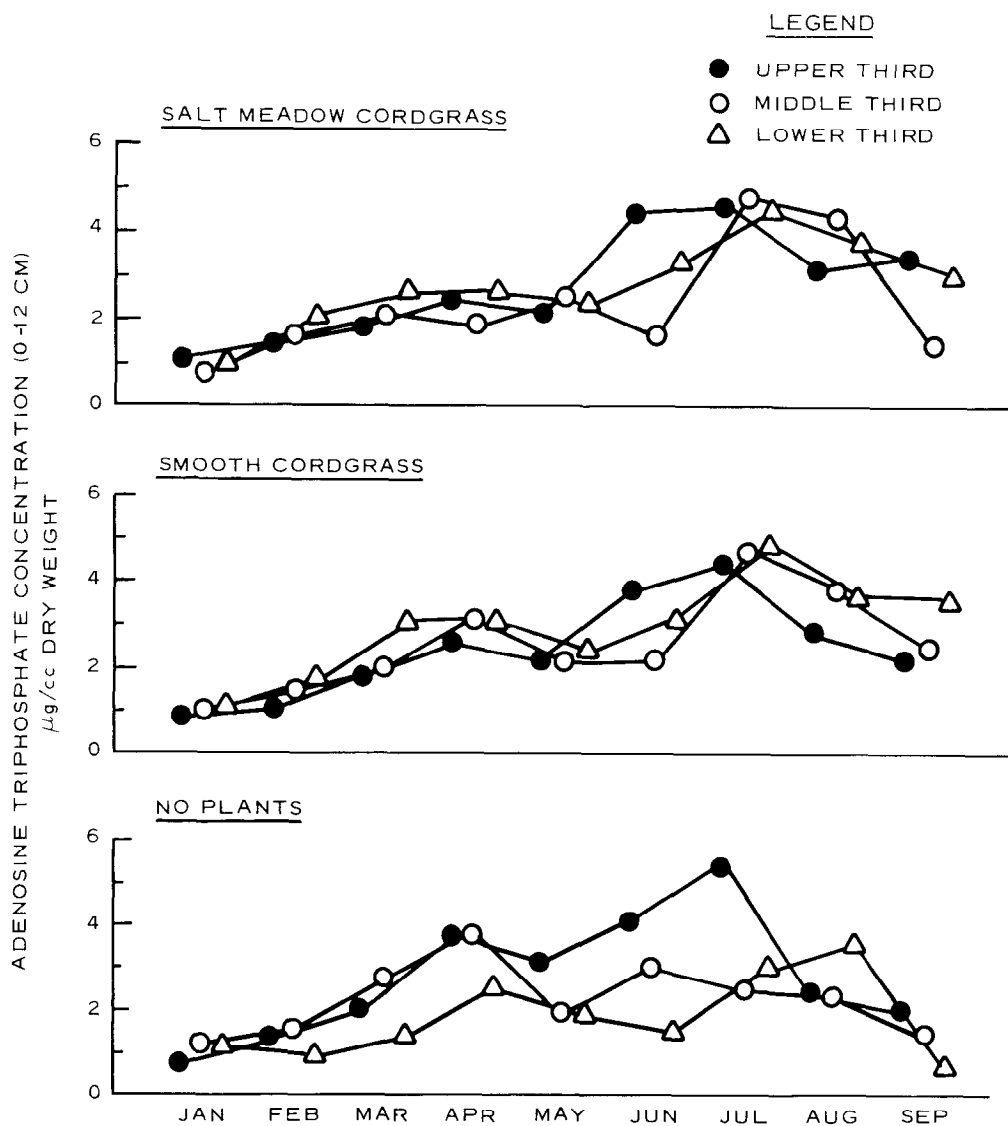


Figure 8. Total microbial biomass by elevational zone in the top 0-12 cm of dredged material in plots with no plants, smooth cordgrass, and saltmeadow cordgrass

Summary and Conclusions

36. The distributions of adenosine triphosphate and bacteria were not related simply to the presence or absence of sediment or the period of inundation. Apparently there were not sufficient differences in the quality and quantity of organic matter in the sediment to cause variation in distribution of microbes. It is noted that these data, collected in an early phase of marsh development, represented only nine months of observation. A longer period of observation may have modified these conclusions.

PART V: ANIMAL RESPONSE

Methods and Materials

37. Use of the study site by animals was documented and contrasted with similar natural areas in the Georgia coastal wetlands. The burrows of fiddler crabs were counted in experimental plots used for the plant propagation study and interpreted with regard to plot treatment. Fish and shrimp were sampled by trawling and seining every two months. Other animal use was assessed every two weeks by sightings or by identification of sign.

Results and Discussion

38. Three species of crabs were present, with the fiddler crab responsible for most of the burrows. Density of burrows was used as an index to natural community development of macroinvertebrate populations. Although seasonal changes in crab activity apparently caused considerable variability in burrow density, Figure 9 illustrates a steady increase in plant density. Burrows were encountered most frequently in the upper third of the intertidal zone and least often in the lower third. The burrows were associated with dense stands of saltmeadow cordgrass and saltgrass, which had their highest biomass in the upper elevation. Unplanted plots had the lowest burrow density.

39. Capture of fish and shrimp with trawls near the experimental site was generally similar to their capture at a natural area several kilometres north in Duplin Estuary (Table 2). Species composition differed somewhat, but anchovy and white shrimp were among the most abundant organisms collected at both sites. The total number of species and their relative abundances at the experimental site were similar in both years of study, suggesting consistency in the waters surrounding the dredged material island. Seining yielded large numbers of grass shrimp (Palaemonetes pugio) from the shores of the island where the experimental site was located.

Table 2. Numbers of Abundant Aquatic Species Captured
by Trawl and Seine

Species	Trawl						Seine	
	1976			1977			Buttermilk Sound	
	Buttermilk Sound	Duplin Estuary	Buttermilk Sound	Duplin Estuary	Buttermilk Sound	Duplin Estuary	1976	1977
<u>White shrimp, Penaeus setiferus</u>	85	181	364	6	13	82		
<u>Common anchovy, Anchoa mitchilli</u>	27	134	31	49	0	4		
<u>Atlantic croaker, Micropogon undulatus</u>	27	17	31	0	0	0		
<u>White catfish, Ictalurus catus</u>	10	0	21	0	0	0		
<u>Stardrum, Stellifer lanceolatus</u>	9	69	12	3	0	0		
<u>Spot, Leiostomus xanthurus</u>	9	13	38	2	1	1		
<u>Hogchoker, Trinectes maculatus</u>	8	1	1	0	0	0		
<u>Weakfish, Cynoscion regalis</u>	8	28	24	0	0	1		
<u>Atlantic herring, Clupea harengus</u>	3	0	4	1	1	0		
<u>Atlantic menhaden, Brevoortia tyrannus</u>	3	4	5	1	1	53		
<u>Striped mullet, Mugil cephalus</u>	2	0	1	0	253	139		
<u>Brown shrimp, Penaeus aztecus</u>	0	21	0	0	0	0		
<u>Atlantic bumper, Chloroscombrus chrysurus</u>	0	25	0	3	0	0		
<u>Squid, Loligo brevis</u>	0	11	0	4	0	0		
<u>Grass shrimp, Pelaeonetes pugio</u>	0	0	10	6	2714	2136		
<u>Atlantic silversides, Menidia menidia</u>	0	0	0	3	42	19		
<u>Atlantic thread herring, Opisthonema oglinum</u>	0	0	0	0	0	74		
<u>Mummichog, Fundulus heteroclitus</u>	0	0	0	0	40	15		
<u>Freshwater goby, Gobionellus shufeldti</u>	0	0	0	0	26	3		

40. Alligators commonly used the planted experimental plots for cover and unplanted experimental plots for sunning. Two diamondback terrapins (Malaclemys terrapin) laid eggs in sand at an elevation on the island that was higher than the experimental site, and banded watersnakes (Natrix sipedon fasciata) were seen in surrounding waters. Both banded watersnakes and alligators are most often associated with fresh water and their abundance around the experimental site reflected the consistently low salinities. Other nonavian visitors included marsh rice rats (Oryzomys palustris), raccoons, and muskrats.

41. Bird use of the dredged material was altered slightly by the planting. Before site preparation, sandpipers and plovers used the sandy shores; swallows, rails, and wrens also stopped briefly as they moved through the surrounding marshes. Use of the site by marsh birds increased as the newly planted marsh developed. Ospreys, terns, and kingfishers were attracted to high perches afforded by stakes and poles used to mark the experimental area. Other species that required open areas continued to use the lower elevational zone and the unvegetated parts of the island. Large numbers of gulls, terns, and oystercatchers continued to use the high sandy ground for resting as they had before the site was planted. No nesting was observed on the site, perhaps because nearby marshes provided better cover.

Summary and Conclusions

42. Animals used the area in similar ways before and after planting. Presumably, some species benefited from the propagation more than others but to what extent is difficult to assess. The burrowing activity of fiddler crabs was associated directly with plant succession, and the greatest activity occurred where plants were most dense. Other species may have benefited from incidental modifications such as perches provided by stakes, the increased shore zone provided by the island, or the rise of sandy land above the surrounding marsh.

PART VI: SUMMARY AND CONCLUSIONS

43. Among the factors tested for their effect on marsh development on dredged material, elevation and the associated amount of inundation had the greatest impact. Out of seven species tested, only smooth cordgrass grew in the lower elevational zone. No other species invaded that zone during the 2.5-yr study. All species planted in the middle elevation survived but none seemed to thrive there. Several invading species from outside the experimental marsh also grew in the middle zone at elevations inundated for less than 14 hr per day. These included water hemp, marsh fleabane, and panic grass. Most of the planted species and many other invading species did well at higher elevations that were inundated less than 6 hr per day.

44. If a major objective of marsh development on dredged material in this region is stabilization of the substrate, then saltmeadow cordgrass and saltgrass should be considered for upper elevations because they eventually form thick fibrous mats of roots. At lower elevations the choice is limited to the only survivor, smooth cordgrass, but it also forms fibrous root masses whenever it can establish itself and resists erosion well. This species can be successfully transplanted any time of the year at Buttermilk Sound. More information of this kind is needed for other promising species for stabilizing dredged material at higher elevations.

45. Fertilization did not appear to facilitate plant survival or performance even though the dredged material had low nutrient concentrations. Apparently the fertilizer was either rapidly transported out of the marsh or it was dispersed uniformly over the entire study area in the interstitial water. Nutrients seemed to be imported naturally via the fine sediments left on the site by the tide. Over the experimental period, nutrients infiltrated deep into the sediments and enriched the substrate for plant growth. In some of the more successful plots, by the end of the study the substrate had approached the quality of natural soils in adjacent marshes.

46. At Buttermilk Sound, seeding was just as effective as

sprigging for all of the species planted. In fact, seeding produced about the same biomass in one year as sprigging did in two years. Under ideal conditions, seeding is an inexpensive alternative to sprigging; however, sprigging is a better tested and less risky propagation technique.

47. Construction of the experimental site and the planting that followed seemed not to have any major effect on aquatic or terrestrial animals. Planting bare dredged material islands will provide habitat for animals that use the vegetation, while animals that use the bare sand will be displaced. In areas where extensive marshes exist such as at Buttermilk Sound, plant propagation may help stabilize the dredged material; but if left unplanted, the site may be more valuable for many animal species and the entire marsh ecosystem by adding habitat diversity. The decision to plant or not to plant in such situations requires a more sophisticated knowledge about fish and wildlife and ecological functions in large marsh systems than now exists.

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1. Buttermilk Sound. 2. Dredged material. 3. Dredged material disposal. 4. Field investigations. 5. Habitat development. 6. Habitats. 7. Marshes. 8. Vegetation establishment. 9. Waste disposal sites. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-26.
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